Chapter 7

HIGHWAY STRUCTURES

Introduction

"Highway structures" generally refer to bridges, although a number of less significant structures are also included in highway projects, such as retaining walls, large pipe headwalls, sign and signal supports, and light poles.

Design of highway structures is usually performed by the Bureau of Bridge Design. There are considerations that the road designer should be aware of as explained in this chapter.

General Procedure

Early in project development (Chapter 2) the designer will recognize the plan elements which require structure design. The need for lead time to design bridges is the chief concern, in part, because additional surveys as well as geotechnical information for foundation design must be obtained. Minor structures such as high-mast lighting bases will not require as much lead time for design but their locations should be established early to allow evaluation of the supporting soils for the foundation and to indicate where right-of-way lines should be placed, or where easements may be required.

Proprietary designs such as Reinforced Earth retaining wall systems will require early coordination, both within the NHDOT and with those providing the design.

Early determination of lead time requirements is made in the Preliminary Design phase. The turnover of plans to Final (or Consultant) Design will include the status of structure coordination.

Structure design may have considerable effect on environmental evaluation. If, at any time, environmental considerations affect the structural concept of bridges or other structures, the designers must be alerted immediately.

The designer should be familiar with the *Standard Specifications for Road and Bridge Construction* (Standard Specifications) (7) Division 500 Structures, as well as the supplemental and addenda specifications dealing with structures. The highway designer will not be responsible for bridge design, but must know the terminology and how the bridge fits into the total plan.

Safety

Above ground structures should be located outside the clear zone. If a structure is located within the clear zone, it should be protected and well marked by guardrail or other barriers.

Sign bases within the clear zone must be breakaway type or also protected. References (44), (28) and (6) contain criteria for safety practices.

Bridge Design

Bridges, as defined by State Law, are all structures of 3.048 m (10 feet) or more in span. Bridge designs are proposed or reviewed by the Bureau of Bridge Design. Coordination between Highway Design and Bridge Design is stressed in earlier chapters and emphasized again in this Chapter. Begin coordination early to provide sufficient lead time. All preliminary coordination must be initiated through the Administrator of Bridge Design. All transmittals to Bridge Design should also be addressed in writing to the Administrator of Bridge Design, Attention to the Designer.

Establishing Bridge Criteria

The following criteria may be used for preliminary line and grade studies:

- Bridge grades should be 1% or more, when feasible, for effective surface drainage and runoff of de-icing chemicals. In constrained areas, e.g., urban or environmentally sensitive, the bridge grade should not be less than 0.5%. For sag vertical curves and Type II crest vertical curves (Figure 4-13), the minimum instantaneous grade on the bridge should meet the above requirements. For Type I crest vertical curves, K values ≤ 32 should be used. This will ensure a minimum grade of approximately 0.5% about 15 m from the crest.
- The approximate depth of the superstructure will be not less than 4% of the span length plus 300 mm.
- The minimum vertical clearance for grade separations is 4.5 m for all roads except interstate interchanges, for which the clearance must be 5.1 m. The minimum vertical clearance must be maintained across the full width and along the length of the overpassed roadway. See Chapter 3 (Figure 3-2) for further information. If there is any doubt as to the clearance to be used, the issue should be resolved with the Highway Design Administrator.
- Structures over waterways should clear a 50-year flood elevation by 1.8 m (100-year flood elevation 1.2 m). The "free-board" clearance is measured from the calculated or recorded high-water elevation (whichever is higher), to the lowest point of the bridge superstructure.
- Structures over railroads should have 6.9 m minimum clearance unless otherwise stated by the Chief of Design Services. (See Chapter 3, Figure 3-2 for additional information.)
- The effect of structures, including bridge rail, on sight distance must be analyzed early, to avoid creating unsafe operating conditions.

Initial Bridge Plan Coordination

After Highway Design has determined that a bridge crossing is required, the preliminary line, grade, and typical section are forwarded to Bridge Design. Bridge Design requests bridge surveys and, later, bridge borings. Preliminary bridge plans are then prepared by Bridge Design for coordination with Highway Design and other agencies, as appropriate.

Highway Design reviews the preliminary bridge plans for general agreement with the highway plans but in particular these items should be checked:

- State and Federal Numbers;
- Station and angle of crossing. Bridge Design should be given a copy of the SDR survey plot, along with the field book pages further describing the bridge area. Geometric data should be checked carefully, particularly if the alignment is curved through the bridge site;
- Horizontal alignments, typical section(s) and superelevation(s);
- Finished grade, original ground and location of profile grade line(s);
- Approach curbs, type of approach railing, roadway rail (or barrier) connection to the bridge rail and rail or other protection of piers and/or abutments;
- Typical sections of the facility to be crossed may be modified to match abutment design. Check effect on drainage and check approach slab effect on catch basins;
- Drainage proximity to piers.
- Adequate provision for utilities and lighting on the structure, including future utility considerations.
- Lowering of the overpassed roadway, or altering the typical section may affect frost protection if abutment/pier footings.

Final Bridge Plan Coordination

When detailed bridge plans have progressed sufficiently, they will be submitted to Highway Design again for review. Check:

- Sheet numbers and total sheets in the project should be verified;
- Check summary of bridge quantities for use of roadway items. The estimated price in the bridge portion of the estimate must match the price used in the roadway portion.
- Earthwork pay limits near the bridge;
- Proximity of blasting required for roadway rock excavation near the existing or proposed bridge. (Special precautionary measures may be required due to the blasting operations.)
- Coordinate with the bridge designer to ensure that all work at the roadway/bridge interface area has been accounted for and that quantities are not duplicated.

- Roadway guardrail post proximity to pier/abutment footings.

At the Preliminary PS&E stage, road plans, draft Prosecution of the Work (POW) and Traffic Control Plan (TCP) and bridge plans should be coordinated with the Bureau of Bridge Design. Preliminary bridge items, quantities and unit prices will be forwarded to Highway Design.

Roadway and bridge estimates must be checked for duplicated items. If duplicate items exist, be sure to show a contract total on the roadway summary sheet.

Retaining Walls

Retaining walls are used to retain earth embankments in areas where space does not permit an appropriate slope to extend to the original ground. Seven (7) types are described here but other systems, variations or combinations of systems may be considered when making comparative estimates.

The need for a retaining wall should be recognized during the Preliminary Design phase. Environmental conditions sometimes influence the choice of wall types and therefore comparative estimates should be available for conceptual reviews as well as for engineering decisions.

Retaining walls are usually designed by the Bureau of Bridge Design or the manufacturer, if the design is proprietary. Highway Design may design certain smaller walls; however, Bridge Design should be consulted to check the design. Others may be involved in approvals of appearance, foundation investigations or right-of-way negotiations. Again, the important consideration is lead time for design, review and decisions.

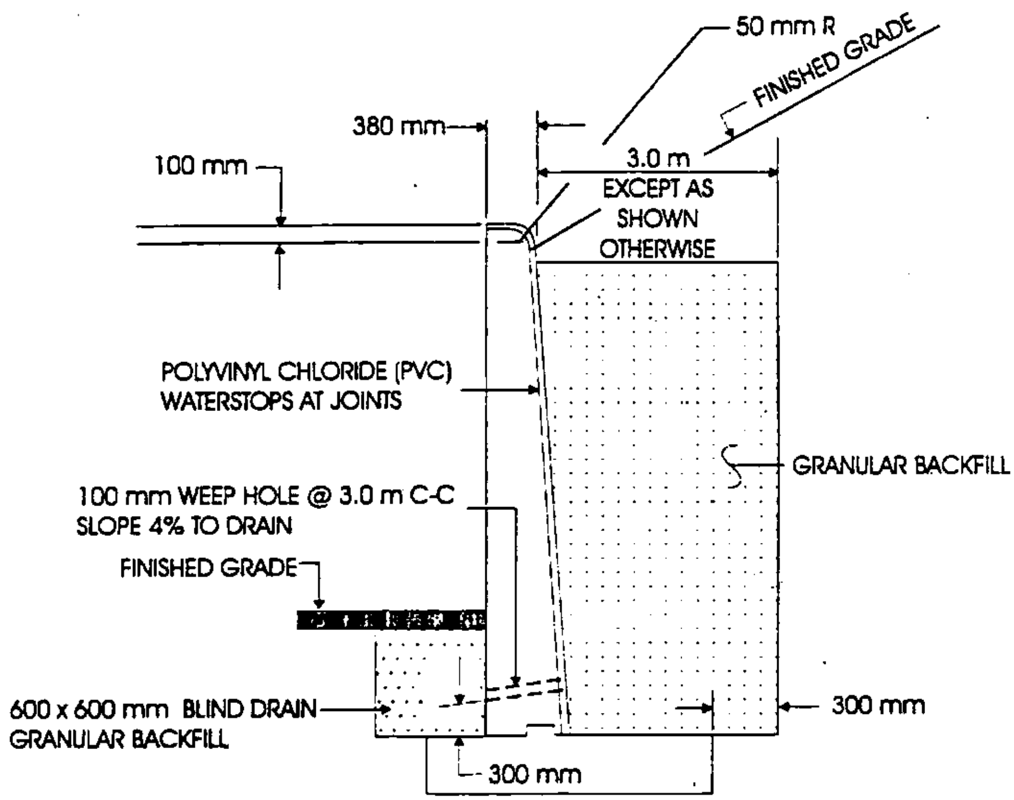
During the Preliminary Design phase, foundation, economic, environmental and right-of-way implications are evaluated with the Bureau of Bridge Design, the Bureau of Materials and Research, and FHWA (overview projects only) to determine the type of structure to be used on the project.

Reinforced Concrete Walls

Mass gravity-type walls may not be cost effective, particularly when high walls are required. The most common walls are of the reinforced concrete cantilever type. Counterforts are required for the higher, thin walls. Figure 7-1 shows the general configuration of the cantilever wall. Dimensions and drainage provisions shown are approximate and are to be specified by the structural designer. The wall face can be surfaced with a variety of textures, patterns and materials which may enhance its appearance, and help blend in with the surroundings.

Figure 7-1

CANTILEVER WALL

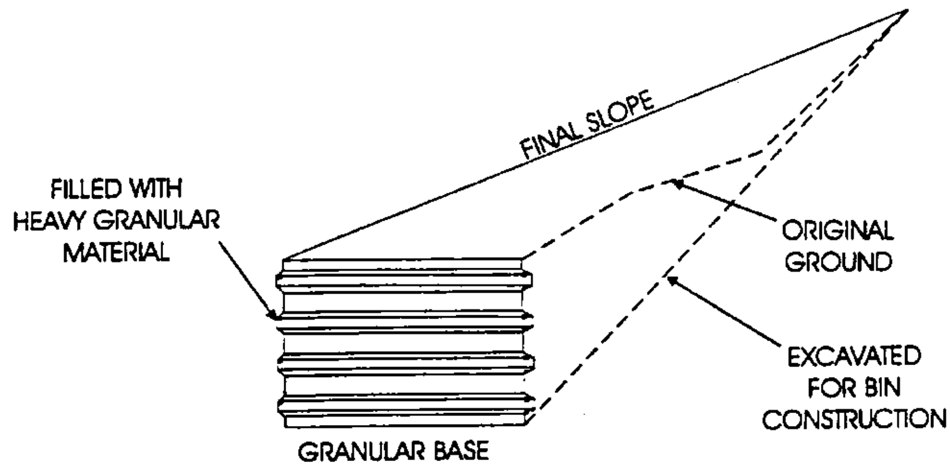


CANTILEVER - TYPE RETAINING WALL
NOT TO SCALE

Bin-Type Walls

Bin-type walls are constructed of modules of interlocking beams of concrete, steel, aluminum, or treated timber and filled with either earth or stone. The chief advantages are flexibility and comparatively low cost. When such walls are considered, they should be identified by the manufacturers' names (if proprietary) and their specifications included in the proposal documents or by reference. Figure 7-2 shows an example of the bin-type wall.

Figure 7-2

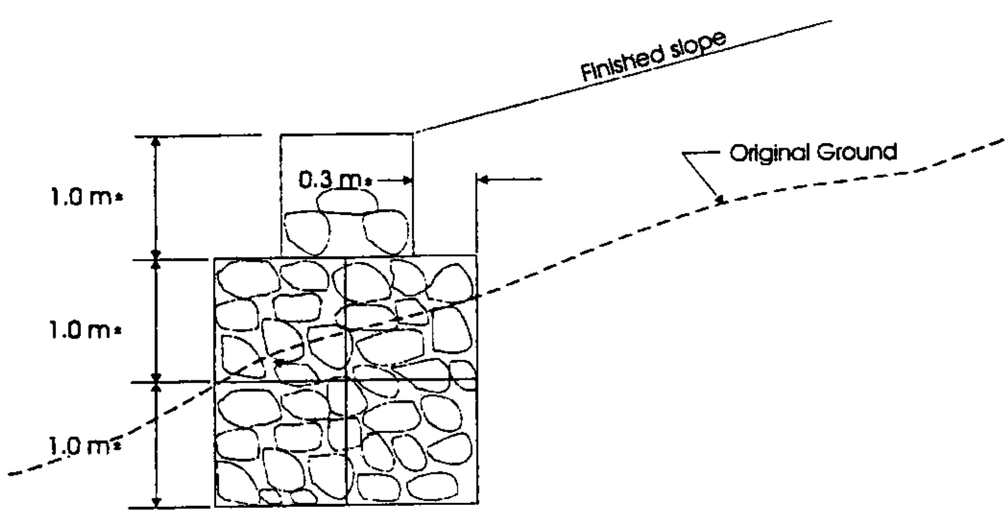


BIN - TYPE RETAINING WALL
NOT TO SCALE

Gabions

Gabions are a type of bin wall that employs wire mesh baskets to contain rock fragments as shown in Figure 7-3. Although gabions can be used for retaining walls, the more common use is for erosion control where poor base soils or washouts suggest a flexible structure.

Figure 7-3



GABION - TYPE RETAINING WALL
NOT TO SCALE

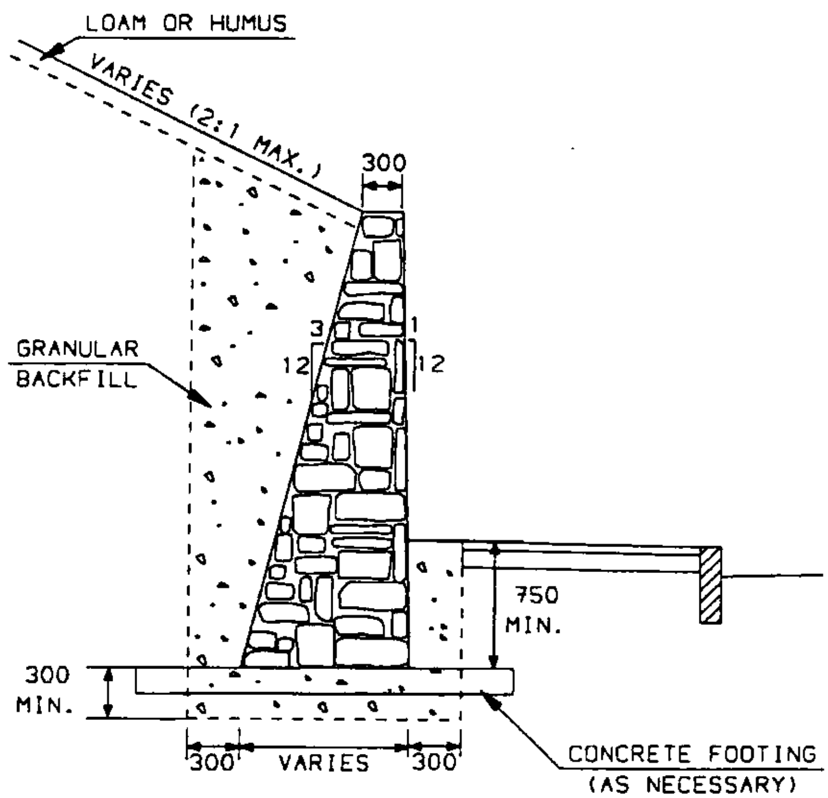
Drainage Structure Headwalls

Large drainage pipes require headwalls for support, erosion prevention, and sometimes for hydraulic efficiency. The headwalls shown in the Standard Plans will normally be adequate for most designs. If a special design is required for hydraulic entrance efficiency or energy dissipation at the outlet end, the Hydraulics Section should be consulted and will usually specify the type to be used.

Mortar Rubble Masonry Walls

Mortar Rubble Masonry (MRM) walls may be used in applications as described for concrete walls except as a very high wall or to support very steep slopes. This type of wall is most commonly used in front of houses or other buildings at the back of sidewalks (see Fig. 7-4) to prevent slope encroachments.

Figure 7-4

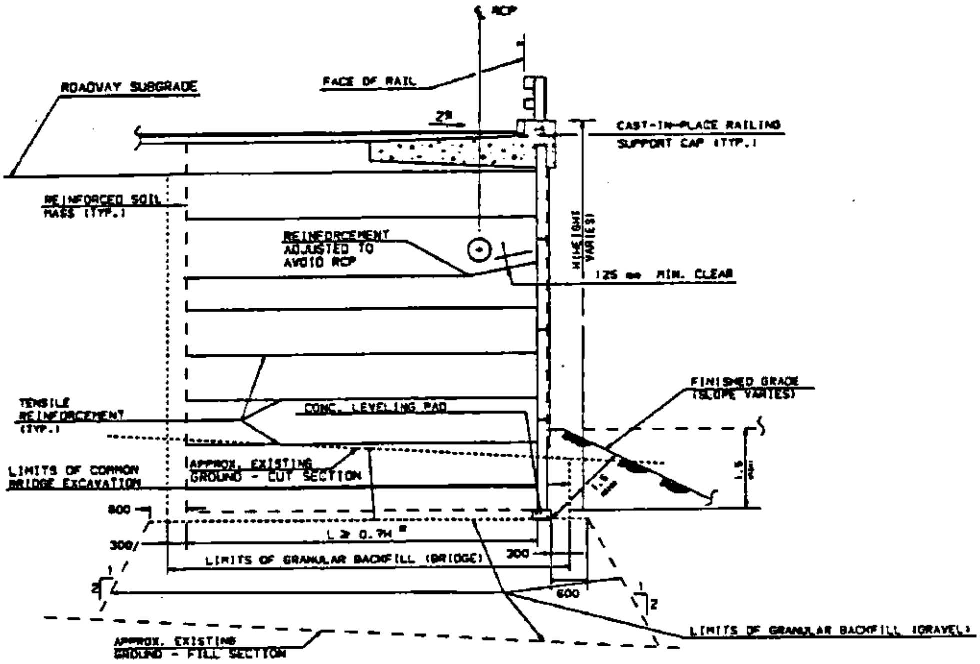


MORTAR RUBBLE MASONRY RETAINING WALL
NOT TO SCALE

Mechanically Stabilized Earth Walls

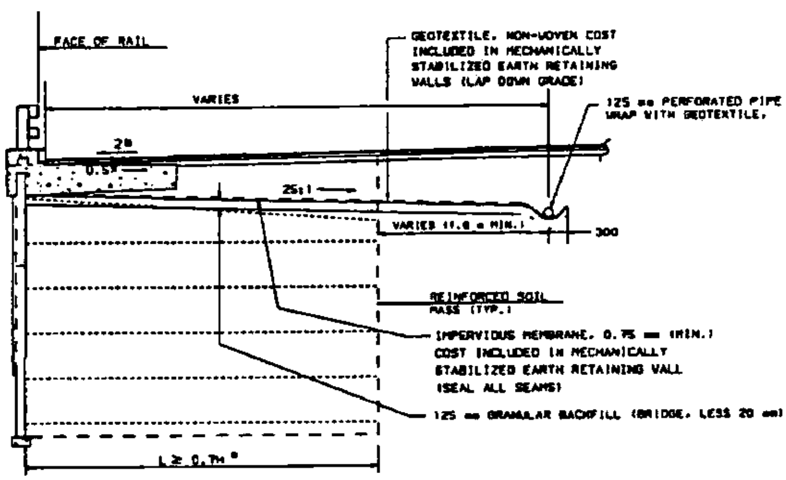
Mechanically Stabilized Earth (MSE) retaining walls employ either metallic or polymeric tensile reinforcements in the soil mass, and a facing element which is vertical or near vertical (see Fig. 7-5).

Figure 7-5



TYPICAL SECTION OF MSE RETAINING WALL

NOT TO SCALE



IMPERVIOUS MEMBRANE LAYOUT DETAIL
FOR MSE RETAINING WALL

NOT TO SCALE

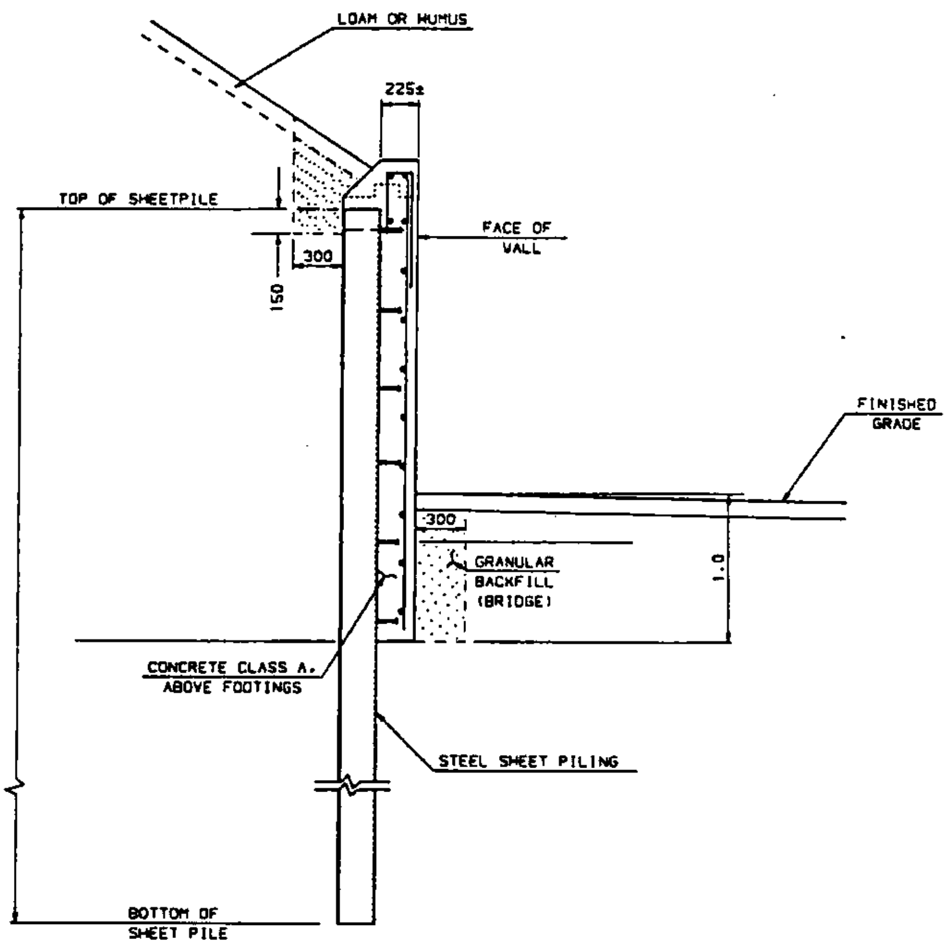
MSE retaining walls are particularly well suited where substantial total and differential settlements are anticipated.

MSE retaining walls should not be used when utilities must be constructed within the reinforced zone or when floodplain erosion may undermine the reinforced fill zone, or where the depth of scour cannot be reliably determined.

Steel Sheet Pile Walls

Steel Sheet Pile Walls are generally limited to a maximum height of 5 m ± unless they are provided with additional support by anchors or tiebacks. This type of wall may be faced with reinforced concrete (which may also be, in turn, faced with stone masonry; see Fig 7-6).

Figure 7-6



TYPICAL SECTION OF SHEET PILE RETAINING WALL

NOT TO SCALE

Sign, Light and Signal Supports

The structures for major signs, luminaries, and traffic signals are usually standard items, designed by the manufacturer and approved for NHDOT use by FHWA. Most foundations for these appurtenances are standard designs approved for normal soil conditions and some are shown in the Standard Plans. Refer to AASHTO publication, *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals* (23) for additional details.

Foundation structures for high-mast lighting, major sign "bridges", or other heavy steel supports are usually designed by the Bureau of Bridge Design, or the consultant responsible for the items, and reviewed by the Bureau of Bridge Design. The designer should be aware of the dimensions to avoid conflicts with new or existing underground installations and the potential hazards for vehicles if the foundation is within the clear zone.

Pavement Structure

Pavement structure is the combination of base course and surface courses necessary to support the traffic load and distribute it to the subgrade or roadbed.

The process for determining the pavement structural components is treated briefly in Chapter 4, Alignment and Typical Sections. The process requires that the Bureau of Highway Design prepare an analysis based upon the Average Daily Load factor (ADL) furnished by the Bureau of Transportation Planning, coordinate with the Bureau of Materials and Research, and obtain approvals from FHWA as part of the P.S.&E. process.

The pavement structure design is based upon the variables of ADL, Regional Factor Soils Support Value, pavement structural component load carrying capabilities, frost penetration, and material availability. There are other factors affecting pavement structure decisions which may override the technical conclusions of the designer, therefore the structural design is tentative until it has final approval by the Highway Design Administrator.

Appendix 7-1 is shown as a reference guide. The designer's conclusions are subject to review until the design is accepted or approved. (Note: The AASHTO Chart 400-2 referred to in Appendix 7-1 is contained in the *1973 Interim Guide for the Design of Pavement Structures*, (25) which is in English units. Until the reference is updated in, or converted to, metric units, the Department will continue to design flexible pavements in English units and convert the pavement structure thicknesses to metric units.)

Recycled pavement must be considered on all Federal-aid projects where pavement materials are to be removed as well as on projects where the surface can be milled and replaced. The Geotechnical Report will contain recommendations for proper methods of recycling.

Removal and replacement of wearing courses is particularly an advantage for urban streets where curb reveal decreases with each overlay. Often the cost of milling is recovered by eliminating the need for raising curbs, catch basin grates, etc. And the material removed can be re-used as base in other projects. Close coordination is needed between the Bureau of be re-used as base in other projects. Close coordination is needed between the Bureau of Materials and Research and the Bureau of Construction to derive maximum benefits from recycling operations.

Additional information about recycling pavement is complied in the FHWA publication, *Pavement Recycling: Executive Summary and Report* (24).

APPENDIX LIST

APPENDIX 7-1

FLEXIBLE PAVEMENT ANALYSIS

The AASHTO Chart 400-2 following the example in this appendix is for a Flexible Pavement, Terminal Serviceability Index (Pt) of 2.5. (A Pt of 2.0 is used for the analysis of pavement overlay only.)

The variables needed to use the Chart 400-2 are Regional Factor, Soil Support Value (S), and Average Daily Load (ADL).

In New Hampshire the following factors are used:

Regional Factor (Takes into account frost penetration.)

Coastal Region	2.0
South and Central Region	2.5
North Region	3.0

Soil Support Value (for the top of each course)

	Range	Use
Crushed stone	8.5 - 9.0	10.0 *
Best crushed gravel base course	8.5	
Average crushed gravel base course	7.0 - 8.0	7.5
Bank run, sandy gravel base course	6.2 - 7.0	6.5
Sand sub-base	5.5 - 6.3	5.5
Original ground	4.0 - 5.0	4.5

* Bureau of Materials and Research prefers to use 10.

Average Daily Load (In the mean year of the twenty-year design period, this factor expresses the weight and number of axle-load applications forecast, in terms of equivalent 18 kip single-axle loads per day.)

The ADL forecast is obtained by request to the Traffic Research Section of the Bureau of Transportation Planning.

The Chart 400-2 provides the nomograph solution for the weighted Structural Number for the material under the layer being examined.

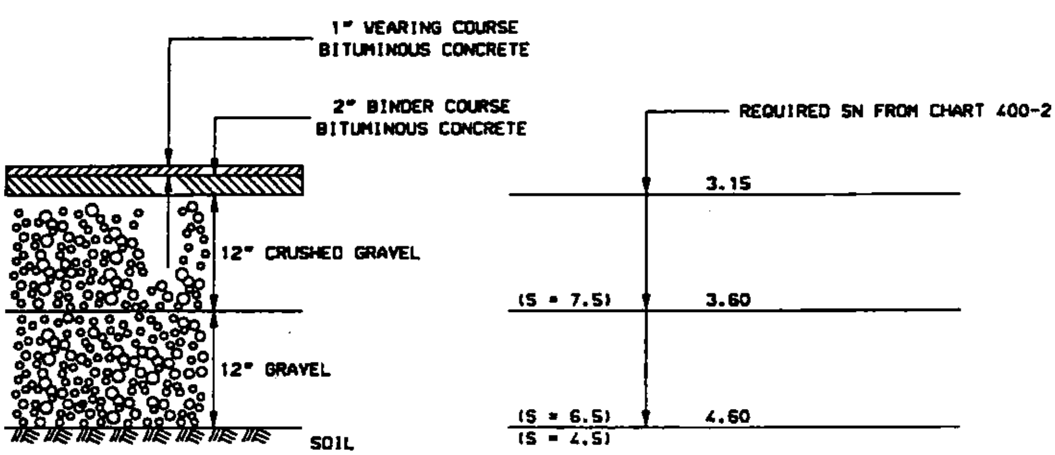
The value obtained from Chart 400-2 is compared to the computed value (accumulated) for the layer being examined using the following pavement component coefficients.

Pavement Component Coefficient Structural Number (SN) (per inch of thickness):

Type of Materials	SN/inch
Bituminous Concrete Pavement (Wearing course, binder course)	0.38
Bituminous Concrete Base	0.34
Road Mix Pavement	0.20
Asphalt Treated Gravel Base	0.24
Crushed Stone Base (fine gradation)	0.14
Crushed Stone Base (course gradation)	0.14
Crushed Ledge Rock	0.10
Crushed Gravel Base	0.10
Bank Run Gravel Base	0.07
Sand Sub-Base	0.05
Stabilized Base	0.17

After computing the pavement structure of the typical section, the computed estimated amounts needed for the project should be sent to the Bureau of Materials and Research together with the proposed pavement design for approval.

EXAMPLE



Proposed pavement and base, given:

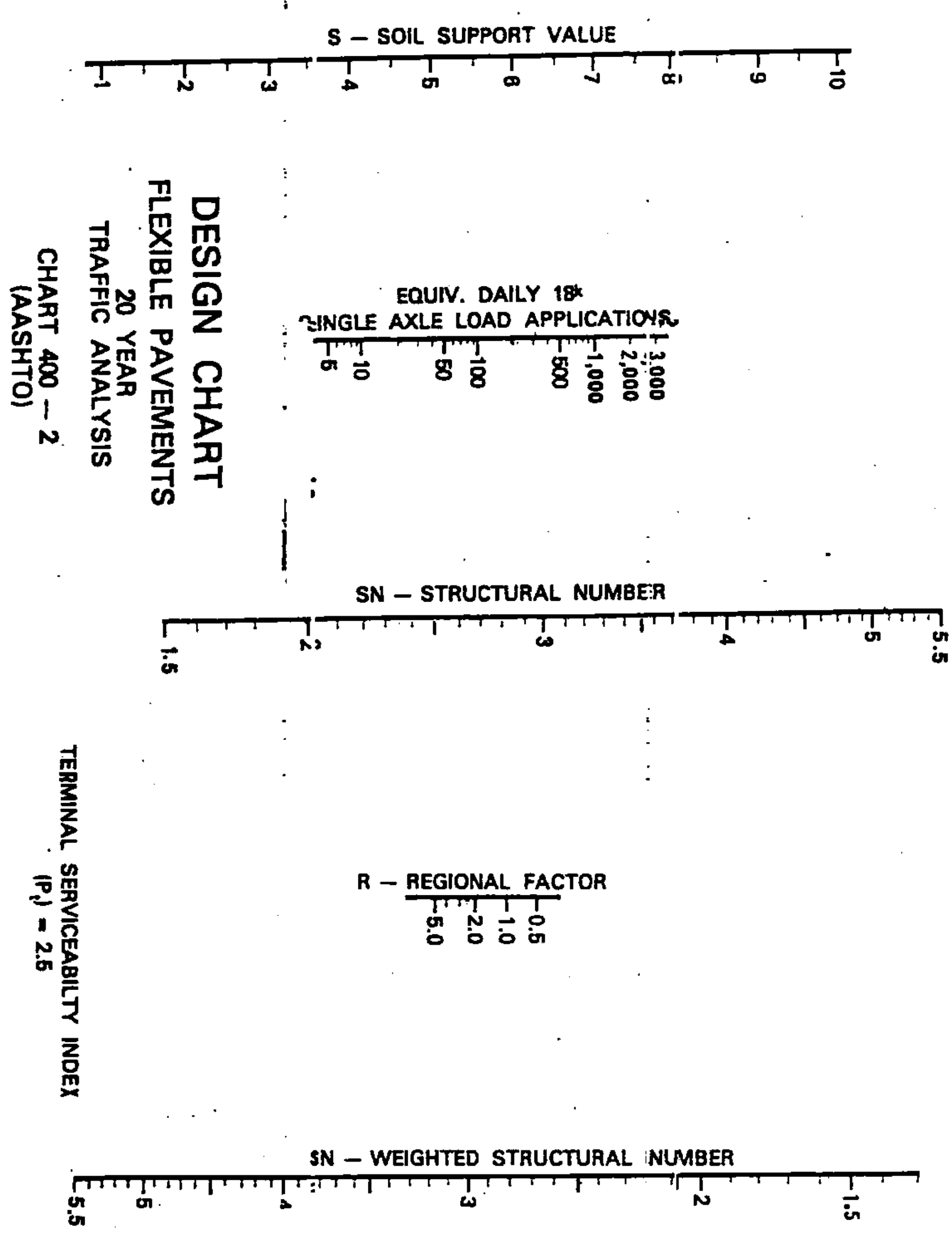
ADL = 575 Pt= 2.5 R.F. = 2.5

Pavement Course	SN/inch	SN (Proposed Pvt.)	SN (Rqr. Chart)
1" wearing course bit. conc.	1" x 0.38 = 0.38		
2" binder course bit. conc.	2" x 0.38 = 0.76	1.14	3.15
12" crushed gravel	12" x 0.10 = 1.20	2.34	3.60
12" gravel	12" x 0.07 = 0.84	3.18	4.60

The difference in surface courses SN (cumulative), 1.14 to the required SN of 3.15 indicates a need for 2.01 (increased bearing strength) or a need for 5.29 inches of additional material (2.01 ÷ 0.38 = 5.29), a total thickness requirement of 3" + 5.5" or 8.5 inches.

When 8.5 inches of wearing and binder courses are proposed the tabulation looks like this and is satisfactory:

		Cum. Total (SN)	Required (SN)
8.5" bit. courses	8.5 x 0.38 = 3.23	3.23	3.15
12" crushed gravel	12 x 0.10 = 1.20	4.43	3.60
12" gravel	12 x 0.07 = 0.84	5.27	4.60


S — SOIL SUPPORT VALUE
1 2 3 4 5 6 7 8 9 10
DESIGN CHART
FLEXIBLE PAVEMENTS
20 YEAR
TRAFFIC ANALYSIS
CHART 400 — 2
(AASHTO)
EQUIV. DAILY 18k
SINGLE AXLE LOAD APPLICATIONS
5 10 50 100 500 1,000 2,000 3,000
SN — STRUCTURAL NUMBER
1.5 2 3 4 5 5.5
TERMINAL SERVICEABILTY INDEX
R — REGIONAL FACTOR
5.0 2.0 1.0 0.5
SN — WEIGHTED STRUCTURAL NUMBER
5.5 5 4 3 2 1.5